US LHC ACCELERATOR PROJECT

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26 July 2001

To: Distribution

From: Phil Pfund

Subject: MQXB Cold Mass Production Readiness Review

The attached report covers the Production Readiness Review (PRR) for the MQXB Cold Mass.

It incorporates comments on previous drafts by the review committee and has been approved by the US LHC Accelerator Project Manager as of Thursday 26 July 2001.

Distribution:

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CERN: T. Taylor, R. Ostojic, M. Bona, R. Vuillermet
KEK: A. Yamamoto
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Production Readiness Review

MQXB Cold Mass

21 June 2001

Introduction

The US LHC Accelerator Project is responsible for providing CERN with integrated inner triplet magnet systems for the four interaction regions at points 1, 2, 5, and 8. Each inner triplet consists of four quadrupole magnets, half of which are designed and built by Fermilab (Q2a and Q2b) and half by KEK (Q1 and Q3). Correction coils are provided by CERN. These elements are assembled into three cryostats – Q1 plus correctors; Q2a, Q2b plus correctors; and Q3 plus correctors – by Fermilab. Fermilab is responsible for the absorbers between Q1 and Q2a (TASA[1]), and between Q2b and Q3 (TASB) to protect the magnets from secondary particles from the p-p collisions at the IP.

The inner triplet quadrupole program includes:

- The design, construction and testing of a series of short (2 m) model magnets in order to develop the design features required to meet the functional requirements.
- The design, construction and testing of two full-scale prototype magnets in prototype cryostats. Testing of the first prototype was largely complete by the time of the review.
- The design, construction and testing of 18 quadrupole magnets, including spares, and the assembly of them and the KEK-provided quadrupoles, together with the CERN-provided correction coils, into complete magnets in cryostats ready for installation in the LHC.

This Production Readiness Review (PRR) covered the MQXB (Q2a and Q2b) inner triplet quadrupole cold masses. It followed a Conceptual Design Review (CDR) that was held in October 1996 and an Engineering Design Review that was held on 16 March 2000. The PRR of the inner triplet cryostat, including the procedures for assembling several magnetic elements into a complete liquid helium cold mass, will be the subject of a separate review later in 2001.

The PRR covered the following items in particular:

- Final design: progress since the EDR, status of specifications, and results of prototype tests.

[1] The absorber designations TASA and TASB are taken from Optics Version 6.3. Previously these absorbers were designated TAS2 and TAS3.

- Materials and parts: detailed design drawings, summary bill of materials and status of parts on order or expected from CERN.
- Quality Assurance Plan
- Fabrication and production control: plant layout tooling and equipment, product flow, travelers, inspection & records, training & qualifications.
- Magnet testing: acceptance plan, test plan, and data exchange.
- Schedule and staffing.

The review was conducted at Fermilab.

Reviewers:

- Phil Pfund, Fermilab, chairman
- Jim Strait, Fermilab
- Doug Fisher, Fermilab
- Ranko Ostojic, CERN
- Akira Yamamoto, KEK
- John Cornuelle, SLAC

Speakers:

- Jim Kerby, Fermilab
- Rodger Bossert, Fermilab
- Jamie Blowers, Fermilab
- Mike Lamm, Fermilab

Others Present:

- Fred Nobrega, Fermilab
- Phil Schlabach, Fermilab

Summary

The US LHC Accelerator Project Manager concluded that the project should continue into full production of the MQXB cold masses. However, the Acceptance Plan and the format for data exchange with CERN have not been finalized. These are discussed further in the following section which contains specific comments and recommendations of the reviewers.

Comments

The following comments were raised by the reviewers and the listed actions are strongly recommended.

1. Acceptance Plan

A draft of the Acceptance Plan was presented. The draft contains a checklist of the tests and checks proposed by Fermilab to be performed on a magnet before it is shipped to CERN. There was extensive discussion on both the specific items on the checklist and on the process for dealing with exceptions. The draft does not address whether there will be tests constituting receipt acceptance when magnets arrive at CERN. The Acceptance Plan does not identify what steps will be taken when test results fall outside of expected ranges. The Plan does not yet define the process by which a magnet is declared acceptable to ship to CERN. While the proposed tests have been discussed with various CERN personnel, the draft itself has not yet been circulated for comment. The US-CERN Implementing Arrangement requires that all such tests be documented in the Acceptance Plan and formally approved by CERN and the US Project.

Action: Fermilab needs to include in the Acceptance Plan the process for dealing with exceptions or deviations from the expected results of the tests and checks, taking into consideration the results obtained on all the produced magnets. The process should identify who, or what group, has the authority to accept deviations.

Action: Fermilab needs to iterate the draft as necessary to obtain a version approved by the US LHC Project Management Office and by CERN. The approved acceptance plan needs to be released in the CERN EDMS.

Several specific comments on the contents of the Acceptance Plan were made.

Action: Include in the Acceptance Plan the possibility to eliminate the second thermal cycle tests in later magnets, and the procedure as to how to approve this change.

Action: Eliminate peak voltage and temperature during quench as acceptance criteria.

Action: Consider whether a tolerance of ±15 units on the ?Gdl is too tight.

2. Data format for magnetic field data

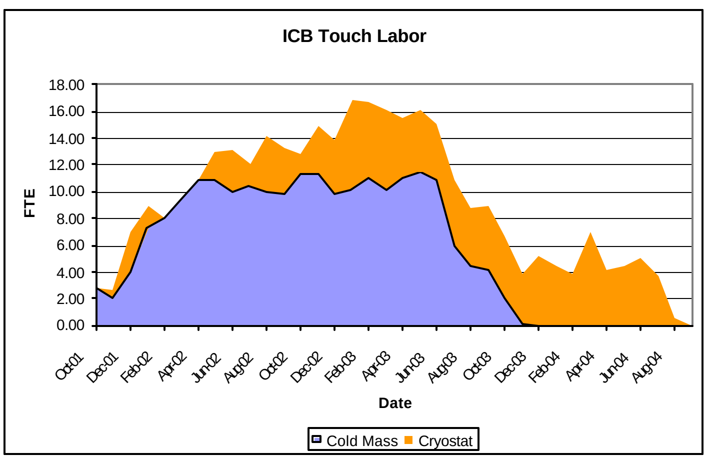
The transmission of magnetic field data to CERN has been under discussion since early in the program. A workshop was convened at BNL in June 1998 to establish a format and procedure for data transfer. The workshop organizers issued minutes and proposed a database format. Fermilab indicated it believes they have a general agreement that they would exchange data with CERN in the form of flat files, but the details still need to be worked out and codified. Fermilab is working with KEK with the intent that both labs would use the same format. KEK pointed out it would like to have the format established by September 2001. It was unclear during the review who, or what group, at CERN is responsible for receiving magnetic field data. Presumably, it is someone in that group with whom the agreement on data format should be reached.

Action: Fermilab and KEK need to finalize the details of the data exchange format that they will use to transmit magnet field data to CERN. They need to reach agreement with CERN on the format by September 2001.

Action: CERN needs to identify to the US labs who will be responsible for the magnetic field data.

3. Process control during production

During the discussion of the system of travelers that Fermilab uses for production control, it was pointed out that technicians will occasionally make notations on a traveler when the process is varied, usually because a section is judged to be not applicable or an alternate action is judged to be necessary. There was extensive discussion regarding production control when this occurs. Fermilab explained that the variations take place under the direction of the floor supervisor who would ensure the appropriate engineers or scientists would be involved as necessary. While the reviewers did not object to this role of the floor supervisor, it was pointed out that the stated practice was not clearly indicated in the travelers which serve both as fabrication instructions and as production control documentation. While Fermilab expressed a confidence in their skilled and experienced crew of technicians, they will soon be doubling the technician crew, from six to 13 or 14, to support full-rate production.



This introduction of several new production workers can be expected to place a greater burden on training and well written instructions.

Action: Fermilab needs to clearly indicate, in the QA plan, in the travelers, or in both, the authorizations and documentation that are required when deviating from the written instructions in the travelers.

Action: Fermilab needs to have a system for training and certifying new technicians in operating procedures and in use of the travelers.

4. Mechanical straightness and twist

Fermilab adheres to a mechanical twist criterion of 1 mrad per 5 meter length and a mechanical straightness criteria of 100 µm per 5 meter length. It was explained that the straightness criterion applied to horizontal straightness. Vertical sag which results from installation in the cryostat is not measured as part of the fabrication of the cold mass. Vertical straightness of the cold mass is not measured since sag due to gravity when installed in a cryostat dominates vertical straightness. Some concern was expressed that some check of straightness in both planes should be made. For example, the vertical straightness could be measured by rotating the cold mass 90?, or by measuring the vertical deflections relative to those expected from gravitational sag. The Functional Specification for the MQXB includes both straightness and twist criteria, but does not specifically state that the straightness is referring to horizontal straightness.

Action: Fermilab should clarify the definition of the straightness tolerance when the MQXB Functional Specification is next revised.

5. Ringing (impulse) test

One of the tests of the coil during production is a capacitor discharge test, or "ringing" test to produce turn-to-turn voltages and to test for internal shorts which are difficult to detect by DC methods. Fermilab conducts the ringing test at 400 V after the cold mass is assembled. KEK conducts a similar test, which they refer to as an "impulse" test. CERN and KEK use a higher voltage (1 kV) and test each coil as it comes out after curing rather than waiting much later in the fabrication process until the cold mass is assembled.

Action: Fermilab is asked to consider impulse testing each individual coil.

6. Hi-pot tests

Fermilab performs four hi-pot tests of the insulation system during fabrication of a cold mass: after collaring, after installing end clamps, after skinning and after final assembly. It was suggested that Fermilab may be conducting more hi-pot tests than are necessary. For example, the test after collaring could be eliminated in favor of testing the insulation integrity in the collared portion after the end clamps are installed, since there would be relatively minor loss of time if a fault were detected only with the second test.

There was also discussion on the level of voltage used for the hi-pot tests. Fermilab uses 5 kV for all hi-pot tests except between quadrants where they use 3 kV. It was pointed out that KEK uses 5 kV for hi-pot tests between quadrants. There was some questioning whether the 3 kV quadrant-to-quadrant voltage used by Fermilab was sufficient, but no conclusion was reached.

Action: Fermilab is asked to reconsider the timing of hi-pot test during fabrication.

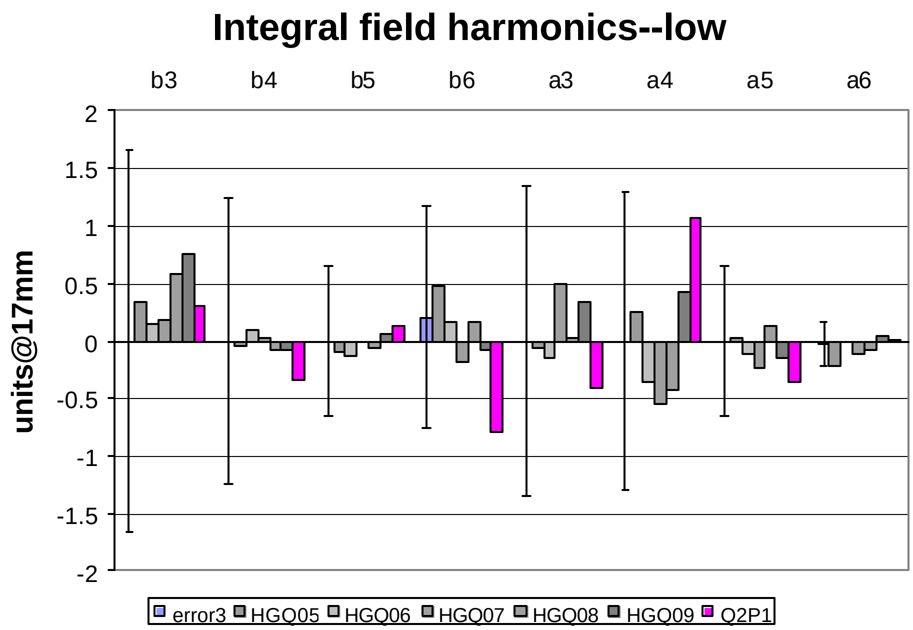
Action: Fermilab is asked to reevaluate the level of voltage used for hi-pot tests between quadrants.

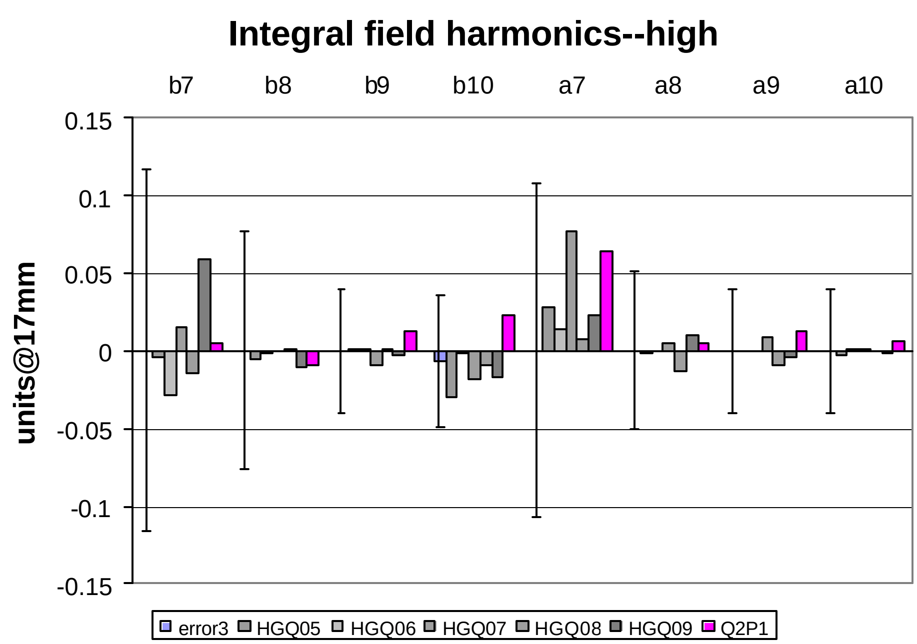
7. Coil aperture

KEK requires that Toshiba check the coil aperture. Fermilab had such a check in the measurement plan but recently removed it.

Action: Fermilab is asked to consider reinstating the coil aperture check in the fabrication process.

8. Sign of b_{10}





The measured integral field harmonics for the first prototype were compared with those of the model magnets. In the measurements presented to the reviewers the harmonics fall within the expected range, although some of them fall close to the limits. It was observed that the b_{10} is of opposite sign from that measured on all of the model magnets. The reviewers questioned whether the change in sign might be due to some variation in assembly. In a clarification subsequent to the review, Fermilab reported no evidence for assembly variation, rather they are still in the process of understanding the new measurement system. They have a choice between two measurements due to the limited number of measurements taken during the test cycles. The first choice has the wrong sign for b_{10} but higher order harmonics which in general are small. The second choice has the right sign for b_{10}, but generally larger higher order harmonics than they believe exist.

Action: Fermilab needs to resolve their understanding of the new measurement system.

9. CERN deliveries of parts

Parts Supplied by CERN	Required	Available	Needed
Strip Heaters	72	14	58
20 gauge wire for strip heaters	684 m	20 m	664 m
26 gauge wire for instrumentation and warm up heaters	2700 m	20 m	2680 m
RTD's	36	0	36
30 gauge wire for RTD's	1296 m	0 m	1296 m

The above table summarizes the instrumentation wires and heaters to be supplied by CERN as presented to the reviewers. As indicated in the table, some of the quantities of parts are already on hand. Fermilab will assemble parts listed above along with beam tubes and corrector subassemblies that are provided by CERN into the completed MQXB. The identities and total quantities of the CERN supplied parts are well known but the delivery dates for remaining quantities will need to be clarified. The corrector subassemblies, most notably the MCBX corrector magnets are critical to the schedule. Fermilab is closely monitoring the progress of the delivery of the correctors, the first of which, a CERN prototype, is expected later in 2001.

Action: Fermilab and CERN need to be clarify delivery dates and quantities of the remaining parts to be supplied by CERN, and CERN needs to ensure timely delivery of parts and components to meet Fermilab's schedule requirements.

Action: Fermilab needs to continue to closely monitor the delivery schedules for CERN supplied parts and corrector subassemblies as well as the few remaining parts that Fermilab will procure directly.

10. Delta ferrite testing

Fermilab has agreed with CERN to perform delta ferrite testing on the longitudinal welds of the cold mass skin. KEK has been also asked by CERN to perform the same test on their cold mass welds. KEK would like to use the same acceptance criteria for delta ferrite testing as Fermilab.

Action: Fermilab is requested to transmit their delta ferrite acceptance criteria to KEK.

11. Current for taking harmonics data

Fermilab presented a proposed specification for integral field harmonics based on Reference Table 3.2 for FNAL magnets. Data used to develop this table were collected during three successive ramps up and ramps down in current and reported at 6 kA. The chosen reporting point of 6 kA caused some discussion since it is only approximately 50% of the full operating field (205 – 215 T/m) where magnetic field quality is of the greatest interest. In a clarification subsequent to the review, it was pointed out that 6 kA was originally chosen to be high enough to avoid low field anomalies, yet low enough be within the range of all of the model magnets. Fermilab reported that during the development program they established that the geometric component of the field harmonics changes little between 6 kA and full field which means that the specification developed at lower current applies as well at full field. Furthermore, steady state harmonic field data on the up and down ramp will be collected at the field levels agreed to at the KEK-US-CERN collaboration meeting in April 2001: 12.3, 100, 185, 200 and 215 T/m.

Action: Fermilab needs to include steady state harmonic field data at all agreed field levels among its acceptance testing and criteria.

12. Ramp rate

There was some discussion on the ramp rates used during training quenches. Fermilab uses 20 A/s. During normal de-excitation of the inner triplet in the LHC, the current rate is expected to be about -30 A/s. There was no concern among the reviewers that both the MQXB and KEK's MQXA could handle these ramp rates.

Action: Fermilab (and KEK) should be aware of the expected de-excitation ramp rate of -30 A/s and, if necessary, perform tests on their prototype magnets.